Space Weather Technical Forecast

Issued on Saturday, 25 November 2023 at 01:28 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Isolated R1-R2 Radio Blackouts likely throughout. Chance of G1 Geomagnetic Storms days 1-2 (25-26 Nov).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate activity has been observed with a peak M1.1 flare at 24/0937 UTC. This source was from AR3499 despite being a relatively magnetically simple area. There are currently twelve sunspot groups on the visible disc, the majority of which are located in the eastern solar hemisphere. In the northeast quadrant some moderately large sunspot groups appear to be magnetically connected. Of these, AR3490 continues to show the presence of two small delta spots in the southern portion of the group. Newly numbered AR3502 also shows the presence of a small delta spot. The largest group is AR3500 in the southeast, which is a compact, bipolar group, and also appears to have a delta spot, with slow growth in penumbra extent. The above mentioned regions make up the majority of the flare risk on the disc at present, with the remaining groups smaller and more magnetically simple at this time.

A CME associated with the M1 flare from AR3499 has been analysed and modelled as a likely miss below Earth orbit, with just a slight chance of a glancing blow on 27 Nov. A LDE C5 flare at 24/2219 UTC from AR3490 appears to have resulted in a CME. More coronagraph imagery is awaited to help determine if an Earth-directed CME has resulted from this.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1 have been largely indicative of a background solar wind regime following the easing of the connection to CH73/+. Wind speeds fell from 380km/s to a minimum of 340km/s around 24/1900 UTC. Since then an enhancement has taken place and speeds have risen, with a discontinuity close to 24/2300 UTC, increasing speeds to between 450-470km/s (Slightly Elevated). This is indicative of a CME arrival at L1, speculated to be from the arrival of the 22 Nov CME from a filament eruption in the SE disc. Solar wind density was generally below average, but increased to average or above average levels from around 24/1900 UTC, with a peak of 16ppcc at 24/2353 UTC. The IMF was at Weak levels for much of the period, but increased to Weak to Moderate levels later in the UTC day, then more persistently Moderate with the CME arrival, peaking at 12nT. The important north-south component (Bz) varied weakly at first, between +3/-4nT. Later in the period and more persistently since the CME arrival the Bz has varied periodically and between +4/-8nT. Phi angle was mostly positive (away from the Sun). Resultant geomagnetic activity was initially Quiet (Kp 1-2), but increased to Unsettled (Kp3) from 24/1800-2400 UTC.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux was generally at Moderate levels, but peaked at High levels (1170pfu) very briefly at diurnal maximum (24/1415 UTC). Following the arrival of the CME late in the UTC day on 24 Nov observed values fell to Background levels again. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) on an increasing, then slightly declining trend. The fluence observation at 25/0000 UTC was 3.72e7 integrated pfu.

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Met Office Space Weather Technical Forecast

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate with further isolated M-class flares (R1-R2, Minor-Moderate) likely and a slight chance of isolated X-class (R3-Strong) flares, mainly from current eastern solar hemisphere sunspot regions. Despite this the recent M1.1 flare was from a relatively magnetically simple area near the southern centre disc.

Solar Wind / Geomagnetic Activity: Two CMEs are expected to affect Earth in the forecast period, with the first having arrived late on 24 Nov and the second arriving late day 1 (25 Nov) or early day 2 (26 Nov). A further CME resulting from the M1 flare from AR3499 on 24 Nov has been analysed and modelled as a likely miss below Earth orbit, with just a slight chance of a glancing blow on day 3 (27 Nov).

Solar winds are currently at Slightly Elevated levels, between 450-470km/s following the recent arrival of a CME at Earth. Speeds may erratically fall towards Background again later on day 1 (25 Nov) ahead of a further CME, either late day 1 (25 Nov) or early day 2(26 Nov) giving more persistently Slightly Elevated speeds again. The next significant coronal hole enhancement is expected on day 2 (26 Nov) with the arrival of CH75/+, giving speeds of up to 500-550 km/s (Elevated) that should broadly persist to the end of the forecast period.

Geomagnetic activity is Unsettled at the time of writing, but likely to soon increase to peak at Active to G1/Minor storm levels early on day 1 (25 Nov) before reducing to mainly Unsettled levels ahead of the next CME arrival late day 1 (25 Nov) or early day 2 (26 Nov) when further Active to G1/Minor Storm conditions are probable. Combined CME and HSS influences may extend slightly enhanced Geomagnetic activity at Quiet to Unsettled levels into day 3 (27 Nov), but should subside to become mainly Quiet by day 4 (28 Nov).

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at Background levels. However, there is a slightly higher risk of observing S1/Minor Storm conditions compared to normal, given the number of sunspots currently on the disc and their propensity to move into a more favourable location on the disc for connection with Earth in the coming days.

Electron flux levels have recently fallen to Background levels following the arrival of the CME from early 22 Nov. Similarly suppressed flux levels are expected over the coming days given forecast combined CME and high-speed stream influence on Geomagnetic activity. High levels of election flux are unlikely to be reached until day 4 (27 Nov) when there is an increasing chance that the reduction in the solar wind pressure following the CMEs and high-speed streams could allow electron flux to subsequently increase.

Fluence levels are expected to remain below the 1e8 Active threshold throughout the period with any notable rise not expected to take place until day 4 (28 Nov) or later.

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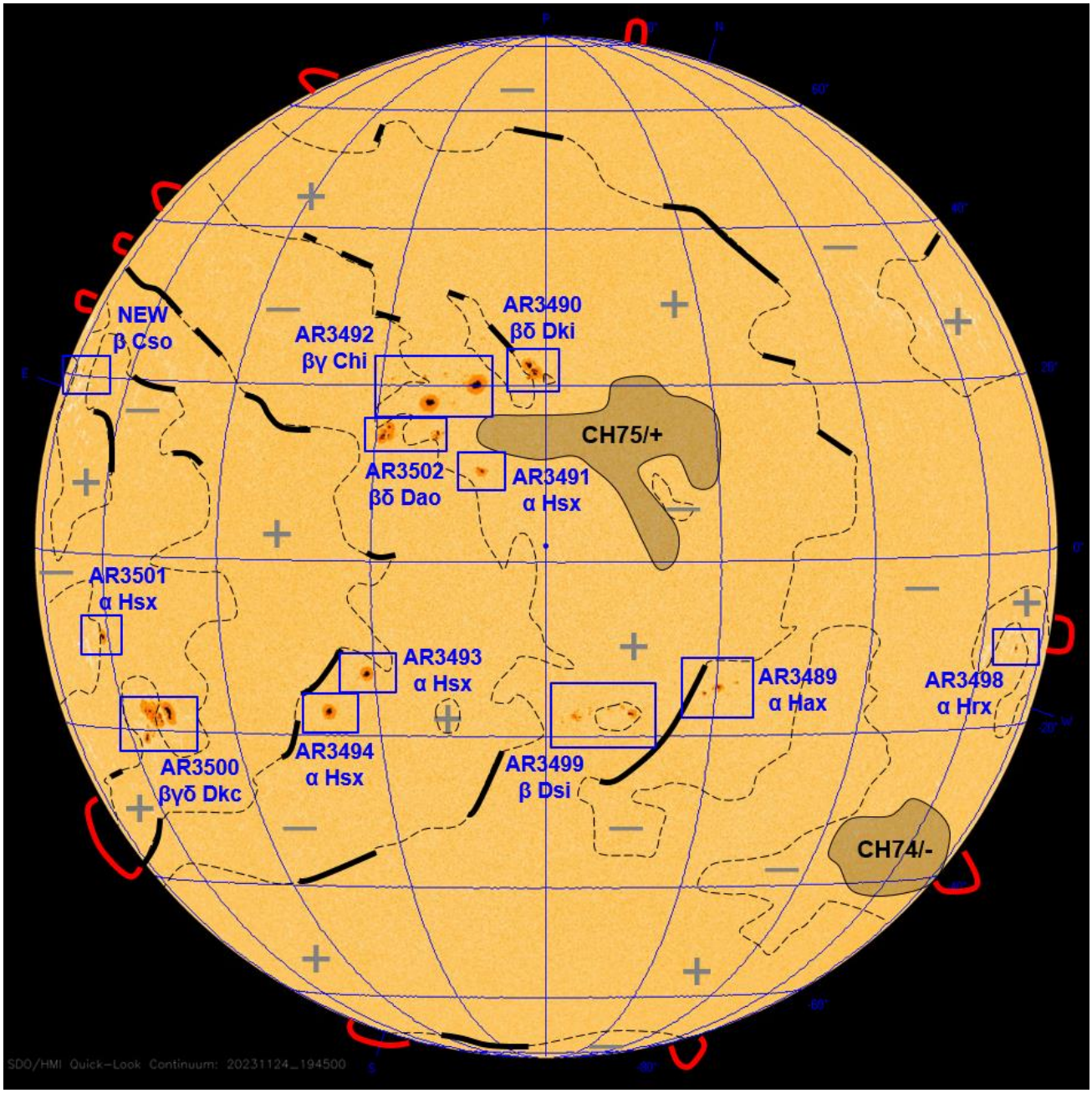
Figure 1. Solar Analysis Valid 24/1945 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

In the past 24 hours a CME associated with the M1 flare from AR3499 has been analysed and modelled as a likely miss below Earth orbit, with just a slight chance of a glancing blow on 27 Nov. A LDE C5 flare at 24/2219 UTC from AR3490 appears to have resulted in a CME. More coronagraph imagery is awaited to help determine if an Earth-directed CME has resulted from this. Other CMEs have been observed leaving the sun, but confidence is high that these are not Earth-directed.

Two Earth-directed CMEs feature in the forecast. The first is from a filament eruption in the southeastern quadrant early on 22 Nov. The observed arrival of a CME at L1 around 24/2300 UTC matches with the modelling and forecast arrival of this feature. A second, partial halo CME is evident in LASCO and STEREO imagery from 22/2100 UTC onwards, directed mainly southwards. A coronal dimming spanning several hours is apparent starting around 22/1930 UTC in the vicinity of AR3489. This is also accompanied by two flare ribbons, indicative of post-eruptive magnetic re-connections in the Sun's corona following a filament eruption. Confidence is moderate for a CME arrival at Earth from this around 26/0000 UTC.

Solar winds are currently at Slightly Elevated levels, having increased to between 450-470km/s following the recent CME arrival. Speeds may fall erratically during day 1 as the CME passes Earth, perhaps falling back to Background levels again ahead of the anticipated arrival of the CME that left the sun late on 22 Nov. Speeds are likely to increase again to Slightly Elevated levels in association with this feature. The next significant HSS enhancement is anticipated from CH75/+ during day 2 (26 Nov). On the previous rotation, this coronal hole was a much larger and darker feature than it appears currently on coronagraph imagery, with speeds then reaching 570 km/s along with a prolonged period of several days at Elevated levels. Geomagnetic activity on the previous rotation was Kp 3-5 (Unsettled to G1/Minor Storm). Therefore it is thought that similar if not a slightly muted version of events will take place upon the connection of the CH75/+ on this rotation. Speeds of up to 500-550 km/s (Elevated) are possible speeds of up to 500-550 km/s (Elevated) and should broadly persist to the end of the forecast period. The arrival of the HSS may overlap with the expected ongoing effects of the late 22 Nov CME, so any enhancement may be initially masked by the effects of the latter.

Geomagnetic activity is Unsettled at the time of writing, but likely to soon increase to peak at Active to G1/Minor storm levels early on day 1 (25 Nov) before reducing to mainly Unsettled levels ahead of the next CME arrival late day 1 (25 Nov) or early day 2 (26 Nov) when further Active to G1/Minor Storm conditions are probable. Combined CME and HSS influences may extend slightly enhanced Geomagnetic activity at Quiet to Unsettled levels into day 3 (27 Nov), but should subside to become mainly Quiet by day 4 (28 Nov).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	50	50	10	5
Strong	G3	No	5	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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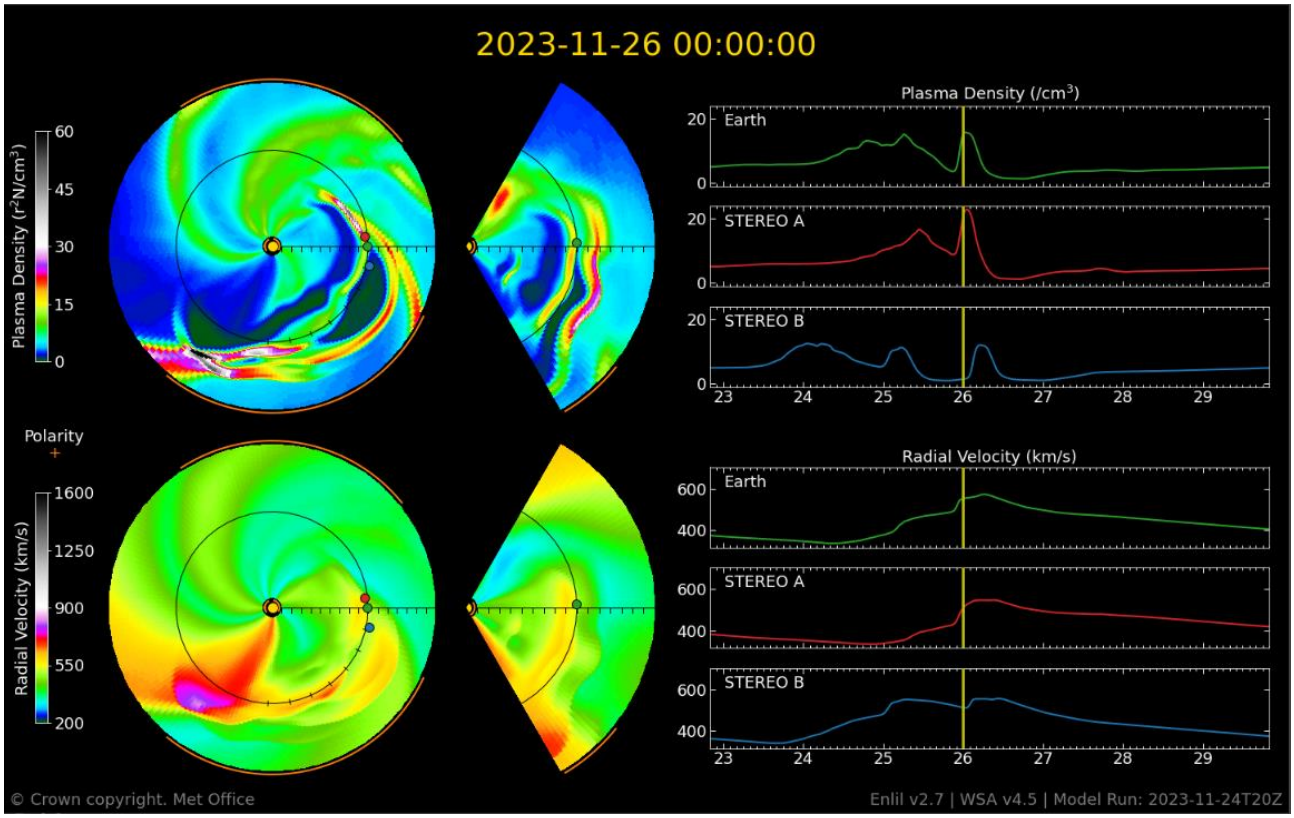
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
22/1241	Partial	Filament Eruption	SE	760 km/s	25/0000 UTC	Arrived at L1 at 24/2300 UTC
23/0535	Partial	Filament Eruption	SE (near AR3489)	540 km/s	26/0000 UTC	Moderate to High confidence in an arrival at L1
24/1707	Partial	AR3499	S Centre disc	522 km/s	27/1500 UTC	Slight chance of a glancing blow

Figure 2: Latest Enlil model output indicating arrival of CME at Earth from late 22 Nov, around 26/0000 UTC.



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Radio Blackouts - X-Ray Flares:

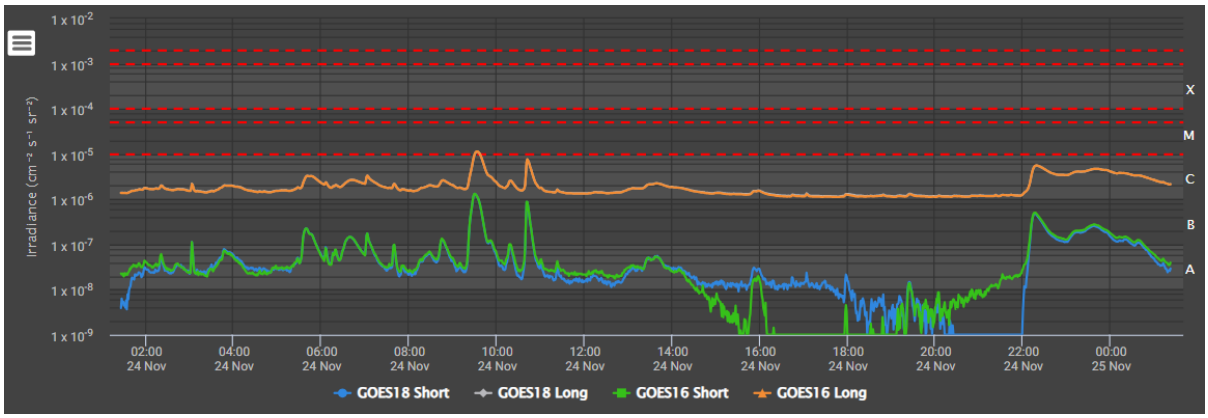
There are currently twelve sunspot groups on the visible disc, with AR3497 having now decayed. The majority of the sunspots are located in the eastern solar hemisphere. The northeast of the disc contains a cluster of sunspot groups that appear to be magnetically connected. What was previously the largest region, AR3492, has been split into two areas, with AR3502 now consisting of the spots to the south of what formerly were associated with AR3492, these southern spots also contain a small, weak delta spot. AR3492 consists of two moderately large leader spots and several weaker and smaller trailer spots, though these appear to be decaying. AR3490 includes two small delta spots adjoined to the main, asymmetric spot. The largest group is AR3500 in in the southeast. This is a compact, bipolar group, and contains a delta spot, with slow growth in penumbral extent. AR3499 near centre disc in the southern hemisphere has shown slow growth of its intermediate spots and some consolidation of the main trailer spot, where some penumbra is now evident. These mentioned regions make up the majority of the flare risk on the disc at present, with the remaining groups smaller and more magnetically simple at this time.

AR3498 will rotate over the western horizon in the coming days. However, occasional CME activity close to, or just beyond the eastern limb and SDO imagery suggests the presence of further active regions that are expected to rotate onto the visible disc in the coming days.

Moderate activity has been observed with a peak M1.1 flare at 24/0937 UTC. The source of this flare was from AR3499 despite being a relatively magnetically simple area. Moderate solar activity is expected to continue with further isolated M-class flares likely, and a slight chance of an isolated X-class flare.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	70	70	70	70
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES 16/18 X-ray flux from past 24 hours



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background levels.

There are several moderately-large, fairly complex regions in the eastern solar hemisphere, which result in a slightly above background risk of an S1/Minor Solar Radiation Storm in the coming days. This risk remains small, but with a minor uptick in probabilities later in the period when these groups move into a more favourable location for connection with Earth, as they move into the western solar hemisphere, apparent from Earth.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

Electron flux levels have recently fallen to Background levels following the arrival of the CME from early 22 Nov at L1. This suppression in flux is broadly expected to continue given forecast combined CME and high-speed stream (CH75/+) influence on Geomagnetic activity in the coming days. High levels of election flux are unlikely to be reached until day 4 (27 Nov) when there is an increasing chance that the reduction in the solar wind pressure following the CMEs and high-speed streams could allow the Van Allen belts to relax and electron flux at L1 to subsequently increase.

Fluence levels are expected to remain below the 1e8 Active threshold throughout the period. The Met Office REFM model forecast will not account for the recently observed and forecast CME arrivals, therefore will likely indicate higher fluence values than should be observed. A rising trend in the Recurrence forecast between days 1 and 3 (25-27 Nov) is based on an earlier arrival time of the high-speed stream from CH75/+ and subsequent recovery of the electron belts on the previous solar rotation. Any notable rise is not expected to take place until day 4 (28 Nov) or later.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	5	1	1	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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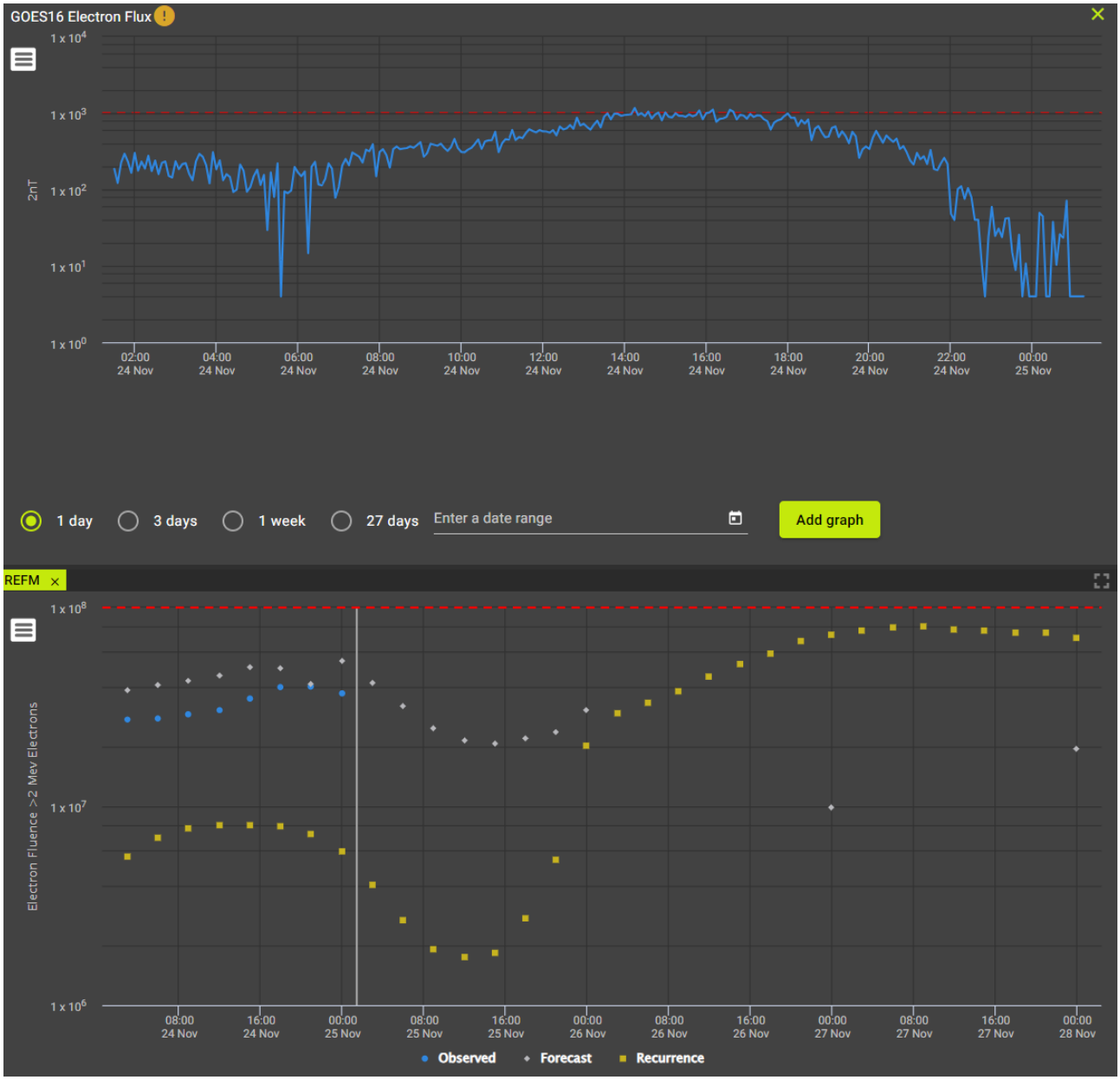
Figure 4: GOES16 >2MeV Electron Flux (above) and MOSWOC Fluence forecast and Recurrence (below)



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